2004 GALVESTON BAY INVASIVE SPECIES RISK ASSESSMENT
INVASIVE SPECIES SUMMARY

Created by: Environmental Institute of Houston, University of Houston-Clear Lake
and the Houston Advanced Research Center

Common Name: Common carp (German carp, European carp, mirror carp, leather carp, koi)
Latin Name: *Cyprinus carpio*
Category: Aquatic Animal
Place of Origin: "Prior to human influence, the common carp was found in the Black, Caspian and Aral Sea drainages, east into Siberia and China and west as far as the Danube River (Balon, 1995) (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."
Place of Introduction: "DeKay (1842) reported that the species was first brought into the United States from France by Henry Robinson of Orange County, New York in 1831 and 1832. In a letter to DeKay, Robinson detailed that he kept the fish in ponds and for several years released one to two dozen carp during the spring in the Hudson River near his residence, thereby creating a commercial fishery for the species. S. F. Baird of the U.S. Fish Commission examined fish taken from the Hudson River, as well as area fish then being sold on the New York markets, and reported that they were goldfish or goldfish hybrids and not true common carp (Redding 1884; Cole 1905). Whitworth (1996) cited early literature indicating common carp had been introduced into Connecticut as early as the 1840s; however, we question the positive identity of the species. Smith (1896) reported that common carp first appeared in the United States in 1872 when J. A. Poppe of Sonoma, California, imported five specimens from Germany and propagated them in private ponds for commercial purposes, mainly distributing them to applicants as a food fish (Smith 1896; Lampman 1946). In 1877, the U.S. Fish Commission imported common carp from Germany and for the next two decades the agency began stocking and distributing the species as food fish throughout much of the United States and its territories (Smiley 1886; Smith 1896; Cole 1905). Now found in all states except Alaska and Maine (http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html)."
Date of Introduction: Unclear, though all records point to 1830s to 1850s (http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html).
Life History: "Reproduction and Fecundity: Over portions of its native range, the carp may be sexually mature as early as by the end of its first year (Kuliyev & Agayarova, 1984). According to Balon (1995) wild carp are portional spawners, spawning two or three times over a 14 day interval. Mating groups of one female and several males swim actively before spawning in flooded grass flats. Eggs are not guarded, but are deposited on grass blades and hatch in three days. Common carp have a relative fecundity of 100,000 to 300,000 eggs per kilogram with reports of as many as 360,000 to 599,000 eggs per female (Moroz, 1968; Bishai et al., 1974; Gromov, 1979; Linhart et al. 1995). Eggs vary from 1.24-1.42 mm in diameter and are yellowish green in color (Moroz, 1968; Linhart et al. 1995) (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."
Growth/Size: "Adults reach 1220 mm TL (Lee et al., 1980). Over their natural range, carp live up to 15 years, with reports of individuals living up to 24 years.(Gromov, 1979; Balon, 1995). Males are known to live longer than females (Balon, 1995) (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."
Feeding Habits/Diet: "Carp are omnivorous, showing some preference for chironomids, cladocerans, oligochaetes, other invertebrates, and plankton and macroalgae (Astanin and Trofimova, 1969). Juvenile common carp may feed on larval fishes, when invertebrates are scarce (Lachner, 1970; Panov et al., 1973). Carp disturb sediments when feeding, increasing water turbidity, which may cause serious problems in certain systems (Lachner et al., 1970) (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."
Habitat: "Trautman (1981) found common carp most abundant in streams enriched with sewage or with substantial runoff from agricultural land, but he reported it to be rare or absent in clear, cold waters, and streams of high gradient (http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html). Salinity Tolerance: The carp is found mostly in fresh waters. Under experimental conditions, feeding rates and growth rates of fingerlings, decline at higher salinity's (Wang, et al., 1997). However, reports exist of this species adapting to brackish waters over portions of its native range (Kuliyev and Agayarova, 1984). Temperature Tolerance: Common carp occur in temperate fresh waters, and are not limited in the Gulf of Mexico drainages, by cold waters. However, warmer waters are required for spawning. Over their natural range Balon (1995) reported 17 °C as the lower limit for spawning. Osipova (1979) reported spawning of wild specimens in the Kubyshev Reservoir, at 15 °C (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."
Attitude (aggressive, etc.): "The common carp is regarded as a pest fish because of its widespread abundance and because of its

tendency to destroy vegetation and increase water turbidity by dislodging plants and rooting around in the substrate, causing a deterioration of habitat for species requiring vegetation and clean water (Cole 1905; Cahoon 1953; Bellrichard 1996; Laird and Page 1996). Available literature indicates common carp may destroy aquatic macrophytes directly by uprooting or consuming the plants, or indirectly by increasing turbidity and thereby reducing light for photosynthesis. . .

There is also evidence that common carp prey on the eggs of other fish species (Moyle 1976a; Taylor et al. 1984; Miller and Beckman 1996). For this reason, it may be responsible for the decline of the razorback sucker *Xyrauchen texanus* in the Colorado River basin (Taylor et al. 1984). In another case, Miller and Beckman (1996) documented white sturgeon *Acipenser transmontanus* eggs in the stomachs of common carp in the Columbia River.

Once established in a water body, common carp are difficult and expensive to eliminate (e.g., Cahoon 1953) (http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html)."

Physical Description: "The common carp can be distinguished from other cyprinids by the heavy and strongly serrate spines in the anterior portion of its dorsal and anal fins, and by the presence two rather long, fleshy barbels on each side of its upper jaw (Douglas, N.H., 1974).

Similar Species: The goldfish, *Carassius auratus*, and the grass carp, *Ctenopharyngodon idella*, are similar. However, both lack barbels and the latter is longer and has a much shorter dorsal fin (Page and Burr, 1991) (http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html)."

Management Recommendations / Control Strategies: include references for existing site-specific strategies

"Fish removal projects have been practiced for hundreds of years, evolving from control of a single species to an approach that considers entire fish communities (McComas 1993, Wydoski and Wiley 1999). To be successful, control methods need to be cost-effective and have minimal impact to other fish (Bonneau 1999). Other factors that need to be considered in selecting a method include size of the water body, water temperature and quality, public opinion, ownership of water, and environmental concerns (Wydoski and Wiley 1999).

The basic methods of control are chemical, mechanical, and biological. Chemical methods are preferred because of ease of application, short time period required to achieve results, and lower cost when compared to other controls. The majority of projects focus on complete removal as partial treatment has varying success. Biological methods consist of using predatory fish, pathogens, and biomanipulation. With biomanipulation, various chemical and mechanical methods are used to adjust the interrelationships among plants, animals, and their environment to achieve a balanced food-web structure. In general, the ratio of piscivorous to planktivorous fish species is the key to stabilizing an aquatic system. Mechanical methods include barriers, commercial fishing, water level manipulation, and traps. Barriers are the most commonly used mechanical method because of their one-time expense and potential effectiveness over several years, whereas most other mechanical methods are considered labor intensive with limited effectiveness from 1 to 5 years (Wydoski and Wiley 1999). Following are the most frequently used methods for controlling common carp.

Rotenone

Rotenone was first used in North America in 1934 and is the most commonly used fish toxicant (Wydoski and Wiley 1999). It is a natural chemical extracted from stems and roots of several tropical plants and is non-selective when applied at dose rates necessary to eliminate carp (Fajt and Grizzle 1993). Absorbed through gills, it inhibits oxygen transfer at the cellular level resulting in suffocation. Rotenone is available as a powder or liquid and can be applied by pump sprayer, boat, aircraft, and constant-flow drip stations in streams. The powder form is less expensive and can be mixed with sand, gelatin, and water to form a paste to use in harder to reach areas such as heavily vegetated shorelines and deep waters. Rotenone is thought to be nontoxic to waterfowl and humans and is also environmentally non-persistent (Wydoski and Wiley 1999). Restocking of fish can occur in the same season of treatment. However, effectiveness only lasts for about ten years unless other steps are taken to prevent return of the lake or wetland to previous conditions (McComas 1993).

Rotenone should be applied at water temperatures greater than 20°C for optimum fish kill and detoxification. Natural detoxification occurs within 2 days to 2 weeks in late summer. Warm water temperatures, high alkalinity, and sunlight in clear waters will accelerate detoxification while turbidity and decreased light penetration in deep water will inhibit the process. Rotenone can remain toxic up to 3 months at low temperatures such as immediately before ice forms on a lake. Fall applications before ice formation eliminate the odor from decomposing fish, reduce the disposal of dead fish, and detoxify by the time the ice breaks up so that restocking can occur in the spring (Wydoski and Wiley 1999).

Effectiveness of the treatment depends on several factors including clarity of the water, dose, fish exposure time, repeated exposure, and life stage. Turbid water reduces effectiveness as does repeated treatments which can cause some fish species to develop a tolerance to the chemical. Dosages and exposure times selected will vary depending on the water chemistry. Carp at different life stages will exhibit different resistances to rotenone, with eyed carp eggs having 50 times as much resistance as larvae (Wydoski and Wiley 1999).

Rotenone applied in the form of treated bait has been less successful for use with carp as they do not readily eat the treated bait. Baiting with corn has been used to concentrate the carp which can then be spot treated with the rotenone (Wydoski and Wiley 1999). For spot eradications to be acceptable, carp need to be concentrated in areas with few non-target fish. This can be accomplished by applying treatment during spawning in areas where the carp's presence is obvious, either through visual observation of spawning activity or high water turbidity (Bonneau 1999).

Rotenone has been successful at eradicating carp as well as all the other fish from lakes in efforts to restock with a more favorable fish community. However, as the Swan Lake restoration demonstrated, eradication is not permanent and additional steps must be taken to ensure that carp populations remain under control. Recommendations made from the study at Swan Lake include installation of a barrier so that carp cannot reenter the lake (Hanson and Butler 1990).

Spot rotenone treatments and rotenone-impregnated baits were tested during restoration of the Bowman-Haley Reservoir in southwestern North Dakota. The reservoir was constructed in 1968 at the confluence of three streams, with construction of a dam for flood control. The shallow, wind-swept reservoir was often turbid and dominated by large common carp (Bonneau 1999). Spot eradication with rotenone applied in the tributaries during spawning periods was the most effective method tested, with 70% of the carp removed between 1994 and 1995. Barriers were set up in the areas treated with rotenone so that remaining carp could not enter these areas. After treatment, water clarity increased, total suspended solids decreased, zooplankton populations increased, and there were no blue-green algal blooms (Bonneau 1999). Rotenone-impregnated bait was fed to carp through automatic feeders installed in the tributaries. The carp were initially fed non-impregnated bait to attract them to the feeding stations. However, when the impregnated bait was introduced, they immediately stopped feeding and there was virtually no fish kill, rendering the method ineffective (Bonneau 1999).

The greatest adverse impact from rotenone control is its high toxicity to many invertebrates and fish. Zooplankton communities can be drastically reduced and usually recover within two to twelve months. With spot treatment, recolonization from adjacent untreated water can occur in as little as one week. At the other extreme, zooplankton communities in cold alpine waters may not recover for two to three years. Reduction in benthic macroinvertebrates varies in response to tolerance, ranging from 0 to 70 percent when rotenone is applied at a rate from 1 to 2 mg/L in freshwater. Typical recovery for benthic macroinvertebrate communities is within two months. Phytoplankton and rooted aquatic plants are not affected by the rotenone (Wydoski and Wiley 1999). In addition to public opposition to the use of toxic chemicals, complete eradication can be costly for large water bodies since it results in elimination of non-target species that will need to be replaced. Complete eradication is, however, the quickest way to achieve dramatic improvements in water clarity, natural revegetation, and desirable fish populations. Combined with other techniques, it could be used to achieve long-term results (Kahl 1991).

Spot treatment is a less costly alternative that receives less opposition and can also be effective when combined with other techniques. However, it produces results more slowly and requires a continued annual effort. It may not be effective in situations where spawning or feeding concentrations are erratic and difficult to isolate (Kahl 1991).

Barriers

When carp are absent from a wetland or lake, barriers such as metal grates can be placed over culverts and streams to prevent future entry of adult carp. Other types of barriers include electrical barriers and velocity culverts that channel outgoing water to produce high velocities that prevent carp from swimming into the water body. Barriers have the disadvantage that initial cost is high compared to other methods because they require construction and installation, as well as future operation and maintenance costs. Adverse effects include interference with spawning runs of desirable fish species and restriction of boats (Kahl 1991). Complete success of metal grates is unlikely since small carp fry can pass through to the water body.

The restoration project at Metzger Marsh included design of a fish control system consisting of five 2-meter wide channels that can be closed individually. It allows native fish access to the diked wetlands while restricting access by common carp. Vertical bar grates with 5-cm wide spacing were placed across three of the channels. The other two channels were fitted with experimental grates that accommodated larger fish. The larger fish were retrieved in a lift basket where they were identified, counted, and measured. The native fish were released into the wetland or Lake Erie and the carp were released into Lake Erie or harvested. The size and shape of the openings were optimized to maximize the passage of native fish into lift baskets and minimize the number of carp handled. Grates used in the initial field-testing in 1999 resulted in the handling of 15% carp biomass. Effectiveness is yet to be determined as testing is ongoing and a final determination of grate size will depend on trade-offs between access by larger native fish and the practicality of handling larger numbers of common carp (French et al. 1999).

While results are not as widely published regarding the use of carp barriers for inland wetlands, projects such as the Middle Bear River Wetland Restoration in southeastern Idaho are underway. The restoration is sponsored by the U.S. Fish and Wildlife Service, Ducks Unlimited, and PacifiCorp and seeks to improve the waterfowl habitat and water quality of the carp-infested wetlands. A five-mile long earthen dike will be constructed to isolate a section of the wetland for carp and sediment control. The dike will have four 48-inch water control structures with rotary fish screens in addition to a 72-inch culvert. The wetlands will be drawn down to concentrate the carp, followed by treatment with rotenone to eradicate the existing carp population (Bear River Resource Conservation and Development 2000).

Harvesting

Harvesting is achieved through seining or trapping. To increase harvesting success in the northern states, long seines are used under the ice in late winter while the fish are schooled. Corn or other bait can be spread in the area to further concentrate the fish. However, seining is not always successful, as carp will dive to deeper water when disturbed (Eddy and Underhill 1974). Another optimum time for harvest is spawning in May. Carp move into sloughs or shallow lakes and are easily found flopping in the weeds. Removal at this time has the additional bonus of interruption of spawning. Once harvested, carp can be sold, used as fertilizer, or ground up for animal feed. Use of trapnets in tributaries is another harvesting technique but is labor intensive and has limited effectiveness (McComas 1993). Trapnetting was evaluated during the restoration of the Bowman-Haley Reservoir and found to be inefficient since only 15% of the fish caught were carp (Bonneau 1999).

Commercial fishing has few adverse effects as there is little impact on non-target species and the cost to agencies and the public is modest. It does, however, require an annual effort and the fish market can be unpredictable (Kahl 1991).

Water clarity improvements

The most ecologically sound method to reduce common carp populations is to improve the water clarity. Sight-feeding game fish such as *Esox lucius* (northern pike) or *Stizostedion viteum* (walleye) can more easily capture carp minnows in clear water. Removing adult carp will also help improve water clarity but other steps need to be taken to sustain the system. The first step is to determine through a lab analysis if algae or suspended mud causes the reduction in water clarity. If the particles settle out, fish, wind, waves, or an incoming stream may be the cause. Options for controlling the turbidity include controls on outboard motors, establishing vegetation beds, shoreline stabilization, erosion control in the watershed, and employment of commercial fishers to harvest the carp (McComas 1993). Once water quality and habitat improvements are implemented, long-term control might be achieved with stocking of appropriate predator species so that populations can be maintained. (Kahl 1991).

Conclusion

The fact that carp control has been carried out for over 100 years indicates the difficulty of completely eradicating it from aquatic systems. While rotenone can eliminate all of the existing carp from a water body, carp can still enter after treatment. Metal grates exclude adult carp from an aquatic system but do little to control the entry of smaller carp. Combined methods such as rotenone treatment followed by stocking with carp predators succeeded at restoring clear waters for a year or two, but there is little information indicating success in the long term.

As mentioned previously, to achieve long-term success, the resilience mechanisms that maintain the turbid water state must shift to those that favor the clear water state. The mechanisms that maintain a clear water state include restoration of riparian, wetland, and macrophyte vegetation; reduction of external phosphorus loading; and reduction in game fish harvesting (Carpenter and Cottingham 1997). In the restorations discussed, two primary goals for undertaking aquatic restoration were to increase waterfowl usage of wetlands (i.e. consumption of macrophytes) and increase angling usage of lakes (i.e. increased fish harvesting). These goals conflict with the changes needed to maintain the clear water state and may cause aquatic systems to shift back and forth between turbid and clear states. Reconciliation of goals with the required changes would be necessary to maintain the clear state.

Another reason for the lack of success in controlling carp can be explained by the absence of barriers to impede its spread. Geography was the initial barrier that was breached when carp were introduced into U.S. waters. Another barrier is clear water since carp are more susceptible to predation by sight-feeding fish. This barrier was removed over time with land disturbances associated with agriculture, industry, and urbanization. As long as these barriers are absent or until new ones are in place, opportunities for carp to spread will continue and periodic control measures will also need to continue (http://www.hort.agri.umn.edu/h5015/00papers/baldry.htm)."

References (includes journals, agency/university reports, and internet links):

1. http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html. USGS Nonindigenous Aquatic Species Profiles.

2. http://www.gsmfc.org/nis/nis/Cyprinus_carpio.html. Gulf of Mexico Program, Species Profiles.

3. http://www.hort.agri.umn.edu/h5015/00papers/baldry.htm. Baldry, Ian. Effect of Common Carp (*Cyprinus carpio*) on Aquatic Restorations. Accessed December 30, 2002.

4. Balon, E. K. 1995. Origin And Domestication Of The Wild Carp, *Cyprinus Carpio*: From Roman Gourmets To The Swimming Flowers. Aquaculture 129:3-48.

5. DeKay, J. E. 1842. Zoology of New-York, or the New-York fauna. Part IV. Fishes. W. and A. White and J. Visscher, Albany, NY

6. Redding, J. D. 1884. Character of the carp introduced by Capt. Henry Robinson about 1830. Bulletin of the U.S. Fish Commission 4(1884):266-267

7. Cole, L. J. 1905. The German carp in the United States. Pages 523-641 *in* Report of the Bureau of Fisheries for 1904. U.S. Department of Commerce and Labor. Government Printing Office, Washington, D.C.

8. Whitworth, W. R. 1996. Freshwater Fishes of Connecticut. State Geological and Natural History Survey of Connecticut, Bulletin 114.

9. Smith, H. M. 1896. A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific states. Bulletin of the U.S. Fish Commission for 1895, 40:379-472.

10. Lampman, B. H. 1946. The coming of the pond fishes. Binfords and Mort, Portland, OR.

11. Smiley, C. W. 1886. Some results of carp culture in the United States. Pages 657-890 *in* Report of the Commissioner of Fish and Fisheries for 1884, Part XII. U.S. Commission of Fish and Fisheries, Washington, D.C.

12. Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press, Columbus, OH.

13. Cahoon, W. G. 1953. Commercial carp removal at Lake Mattamuskeet, North Carolina. Journal of Wildlife Management 17(3):312-317.

14. Bellrichard, S. J. 1996. Effects of common carp (*Cyprinus carpio* on submerged macrophytes and water quality in a backwater lake on the upper Mississippi River. Master's thesis, University of Wisconsin-La Crosse. Reprinted by the National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin. LTRMP 96-R008. 44 pp.

15. Laird, C. A., and L. M. Page. 1996. Non-native fishes inhabiting the streams and lakes of Illinois. Illinois Natural History Survey Bulletin 35(1):1-51.

16. Moyle, P. B. 1976a. Inland fishes of California. University of California Press, Berkeley, CA.

For additional references, see the Annotated Bibliography.

Available Mapping Information:

USGS Nonindigenous Aquatic Species Profiles. **http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html**